Relationships between Collembola and their environment in a maritime Antarctic moss-turf habitat

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INTRODUCTION

Compared with temperate or boreal acidic peat habitats, the arthropod fauna of Antarctic moss-turf habitats is species poor. Geographical isolation and the lack of a continental pool of potential colonizers are at least as important as the harshness of the Antarctic environment in maintaining this low species diversity.

Low species diversity is also a feature of the plant populations. Moss-turves in the maritime Antarctic develop on gently sloping, stable sites, and are usually formed by two mosses, *Chorisodontium aciphyllum* (Hook, f. & Wils.) Broth. and *Polytrichum alpestre* Hoppe. A semi-ombrogenous peat accumulates below the green surface zone of production (Allen & Northover 1967). The relative simplicity of this naturally occurring system lends itself to observation, sampling and experimental manipulation, which are designed to investigate the inter-relationships between the soil fauna, the plant species and their environment.

SITE AND METHODS

The study site, on Signy Island, South Orkney Islands (60°43′S, 45°36′W), was described by Tilbrook (1973), and Davis (1981) summarized the biological studies. Only two species of Collembola occur regularly in this habitat: the more numerous, *Cryptopygus antarcticus* Willem, which is a widespread and abundant Antarctic species, and *Friesea woyciechowskii* Weiner, which is currently known only from the South Orkney and South Shetland Islands. *C. antarcticus* is a typical isotomid Collembola, with mandibles that possess a well developed molar plate, and it feeds on algae, fungi and other plant material (Broady 1979). *F. woyciechowskii* has the biting type of mouthparts typical of the genus, and although its diet is unknown, it is probably carnivorous. Thus, the two species are unlikely to be competing for the same food resource. Two other species of Collembola, *Parisotoma octooculata* (Willem) and *Archisotoma brucei* (Carpenter), occur rarely at the site, although both are numerous in other habitats on Signy Island.

Contiguous samples, rather than random cores, were collected to study the vertical and horizontal distributions of the Collembola and to investigate the effects of the environmental variables on these observed distributions. A single block of moss and peat, 20 cm square and at least 9 cm deep, was collected on each of four sampling occasions during the 1980–81 austral summer. Each block was cut vertically into sixteen square cores, each 5 cm square and arranged in a contiguous pattern of four by four. Each core was sectioned horizontally into six samples, yielding ninety-six samples for each block. The surface sample comprised the green moss and upper dying leaves and was approximately 1·5 cm thick, and the five subsequent samples were each 1·5 cm thick. The moss cover of the surface layer of each core was estimated, the arthropods were extracted from the samples by high gradient heat extraction, and the dried plant material was returned to the UK for chemical analysis (analytical methods follow Allen *et al.* 1974).

RESULTS

Figure 1 shows the vertical distribution of *Cryptopygus* and *Friesea* in the moss-turf. *Cryptopygus* occurs predominantly at or near the surface, with 55% of its population in the surface layer (0–1·5 cm). Only very few individuals are likely to occur below 9 cm deep. In contrast, *Friesea* occurs commonly over a broader depth range, although it was absent from the surface layer. An unknown proportion of the population occurs below 9 cm.

Calculation of the variance to mean ratio showed that *Cryptopygus* was strongly aggregated, especially in the upper three layers, and that *Friesea* was strongly aggregated in the deeper layers of the moss-turf. However, when only small numbers of individuals were present in a layer, it was not possible to examine dispersion using this ratio. An estimate of b, the slope of the regression of the logarithm of variance on the logarithm of mean, was used as an index of aggregation (Taylor 1961). Values for b of 1·55 and 1·50 were obtained for *Cryptopygus* and *Friesea* respectively. Both values were significantly greater than unity ($P < 0{\cdot}001$), the value expected for a Poisson distribution (which is the null hypothesis, i.e. randomness). Thus, overall, both species were strongly aggregated. The physical and chemical characteristics of the moss-turf were examined to investigate some possible

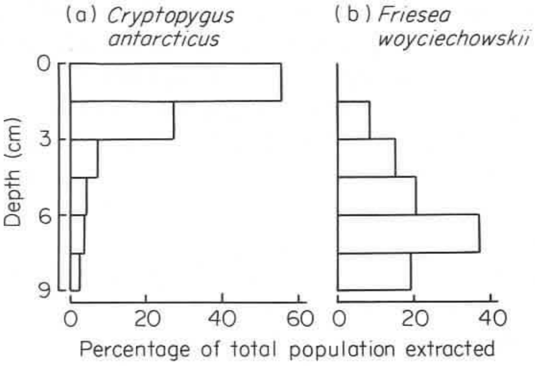

FIG. 1. The vertical distribution of the two most abundant species of Collembola. The numbers are expressed as percentages in each of the six layers for the four blocks combined: the total numbers extracted were 2119 *C.* antarcticus and 121 *F. woyciechowskii*.

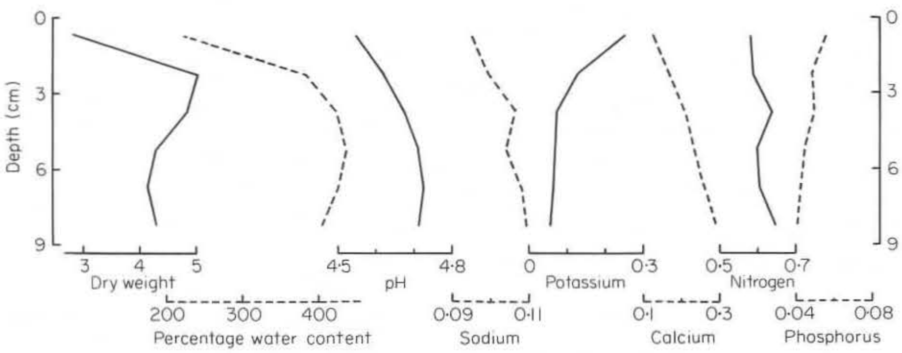

FIG. 2. The vertical distributions of eight measures of the physical and chemical environment of a block of moss-turf collected from Signy Island on 23 January 1981. For each variable, the six layer means ($n = 16$) have been plotted. Solid lines represent the upper set of horizontal axes, dashed lines the lower set of axes. Chemical concentrations are expressed as a percentage of sample dry weight.

causes for both the aggregations and the differences in vertical distribution of the two species.

Eight physical and chemical characteristics of the environment were determined for all samples. Figure 2 shows the vertical distributions of these environmental data for 23 January 1981, i.e. during the middle of the summer. Vertical trends are evident in many of the variables in this block, but, in particular, dry weight, percentage water content, potassium and calcium showed consistent trends in all four blocks.

The effect of the physical and chemical environmental factors on the distributions of *Cryptopygus* and *Friesea* was examined in two zones. A principal components analysis had shown that the arthropod populatios could be subdivided (Usher & Booth 1984): the green moss zone comprised the top layer data, and the dead moss zone comprised the moss-turf below 3 cm in depth. The transition between the two zones occurred within the second layer (1·5–3 cm), so these data were omitted from the analyses because they were intermediate.

In the December 1980 block, there was a positive correlation between percentage water content and counts of *Cryptopygus* in the surface layer, but a negative correlation in the dead moss zone. There was a significant positive correlation in the green moss zone on 20 February 1981, but all other correlation coefficients were not significant. Figure 3 suggests an optimum range of percentage water content (correlations not significant), and extremes where an influence was exerted on the distribution of *Cryptopygus*. Percentage water content appeared to have no influence on the distribution of *Friesea*.

In the green moss zone, multiple regression equations relating the numbers of *Cryptopygus* to the environmental factors were statistically significant in three of the four blocks. Percentage water content and sodium consistently contributed positive and negative regression coefficients respectively, whilst *Polytrichum* cover contributed one positive and one negative coefficient. All the remaining variables (dry weight, pH, potassium, calcium, phosphorus and nitrogen) were incorporated

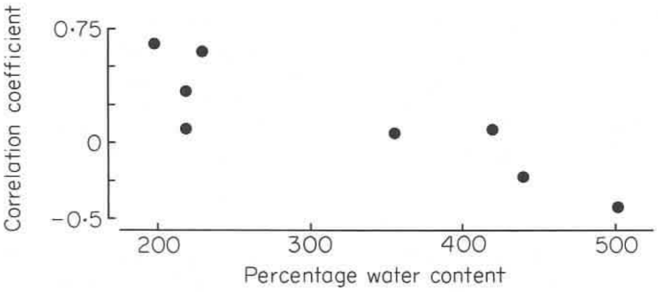

FIG. 3. Scatter plot of the correlation coefficients (between percentage water content and the numbers of *Cryptopygus*) plotted against the mean percentage water contents of two zones for four blocks of samples. The four points to the left relate to the green moss zone, and the four points to the right to the dead moss zone.

only once each (Booth & Usher 1984). In the dead moss zone, again three of the four multiple regression equations were significant. The coefficients for calcium were consistently negative in all three blocks. Potassium was incorporated into two of the equations and both coefficients were negative. Three other variables (*Polytrichum* cover, sodium and phosphorus) were incorporated once each. The percentage of the variance accounted for by the regression equations varied between 14 and 25%

The influence of the environment on the distribution of *Friesea* in the dead moss zone appeared to be slight. Although the regression equations relating *Friesea* to the environmental variables were all statistically significant (the December 1980 block was excluded as it contained only a single *Friesea*), they accounted for only between 8 and 12% of the variance.

DISCUSSION

The strongly aggregated distributions of the two Collembola species are typical of many soil arthropods. Can the causes of these aggregations be identified? Usher (1976) reviewed a variety of field studies and concluded that both the physical and chemical environment could influence the location of arthropod aggregations. Food location was an important factor in laboratory studies, but its influence in the field was uncertain.

Cryptopygus and *Friesea* aggregated to a similar extent, but they differed markedly in their response to the environmental factors. The influence of *Polytrichum* cover was not consistent, although it was incorporated into five of the nine regression equations. Plotting the values of the correlation coefficients between *Polytrichum* cover and the Collembola counts against the mean *Polytrichum* cover for each block (as for percentage water content in Fig. 3) showed no recognizable trend for *Cryptopygus*, but suggested that *Friesea* may favour areas of high or low *Polytrichum* cover (the latter implying high *Chorisodontium* cover), and avoid areas of intermediate cover. Percentage water content only appeared to influence the distribution of *Cryptopygus*. The chemical characteristics of the environment appeared to have a greater effect on the distribution of *Cryptopygus* than did the physical factors. Sodium was important in the green moss zone, and calcium and potassium were important in the dead moss zone. The observed influence of the chemical variables on *Friesea* was small compared to their influence on *Cryptopygus*.

Which other environmental features might be structuring the arthropod community? Competition for food supply and predation pressure can be considered. Competition between these two species of Collembola is unlikely, and thus cannot explain the differences in their vertical distributions. The small prostigmatid mite, *Nanorchestes berryi* Strandtmann, is a surface dwelling, algal grazer, whose food requirements and distribution overlap with those of *Cryptopygus*. Another prostigmatid mite, *Ereynetes macquariensis* Fain, occurs in the dead moss zone and is a potential competitor with *Friesea*, although little is known of the food requirements of either species.

The moss-turf supports a single species of arthropod predator, the mesostigmatid mite *Gamasellus racovitzai* (Trouessart). *Cryptopygus* contributed about 80% of all food traces found in a field population of *Gamasellus* (Lister, in press) and Usher & Bowring (1984) estimated, from laboratory studies, that *Gamasellus* could remove annually some 6–8% of the population of *Cryptopygus* from a moss-turf habitat. Since the predator captures prey mainly from the larger size classes of *Cryptopygus*, it may have a disproportionate effect on the potential breeding population. In the moss-turf *Gamasellus* had a similar vertical distribution to *Cryptopygus*, its preferred prey (Usher & Booth 1984).

Does *Friesea* avoid predation by occurring deeper in the moss-turf profile or does it rely on a means of chemical defence? Unfortunately, there are no laboratory or field data available on interactions between *Friesea* and *Gamasellus* to answer these questions. The value of flocking behaviour as an anti-predator strategy by vertebrates has been widely discussed (e.g. Krebs & Davis 1981): is it possible that predation pressure on invertebrate populations (e.g. *Cryptopygus* in the moss-turf) is a contributory influence to microarthropod aggregation?

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